Long-term effects of a dyadic planning intervention with couples motivated to increase physical activity

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Abstract: Objective: In dyadic planning a target person and a planning partner create plans for when, where, and how the target person will change a health-relevant behavior. Across 52 weeks, direct and indirect effects of a dyadic-planning intervention on moderate-to-vigorous physical activity (MVPA) and physical fitness in target persons and their partners were investigated in a randomized controlled trial. Relationship quality was explored as a moderator. Methods: N = 338 couples (target persons randomized) were randomly assigned to a dyadic-planning- (DPC), an individual-planning- (IPC), or a no-planning dyadic-control condition (CC). MVPA was objectively assessed four times across 52 weeks using accelerometry. Physical fitness and proposed mediators (individual action control, received behavior-specific support and control) were repeatedly assessed. Relationship quality was measured at baseline. Latent growth curve-, multi-level-, and manifest mediation models were fit. Results: Across 52 weeks, MVPA of IPC and CC target persons increased. MVPA of DPC target persons remained stable, but those who reported high relationship quality increased their MVPA over time. DPC partners showed steeper increases in physical fitness when compared to IPC partners, but not CC partners. DPC partners' increases in physical fitness were mediated by received support from target persons. Conclusions: The dyadic planning intervention showed non-beneficial effects for target persons' MVPA, but beneficial effects on their partners' fitness. These findings resemble evidence from the social support literature indicating more benefits for support providers than for recipients.

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Long-term effects of a dyadic planning intervention with couples motivated to increase physical activity☆

Jan Keller[a,*], Diana Hilda Hohl[a], Georg Hosoya[a], Silke Heuse[b], Urte Scholz[c], Aleksandra Luszczynska[d,e], Nina Knoll[a]

[a] Freie Universität Berlin, Germany
[b] University of Applied Sciences Europe, Campus Berlin, Germany
[c] University of Zurich, Switzerland
[d] SWPS University of Social Sciences and Humanities, Poland
[e] University of Colorado at Colorado Springs, USA

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ABSTRACT

Objective: In dyadic planning a target person and a planning partner create plans for when, where, and how the target person will change a health-relevant behavior. Across 52 weeks, direct and indirect effects of a dyadic-planning intervention on moderate-to-vigorous physical activity (MVPA) and physical fitness in target persons and their partners were investigated in a randomized controlled trial. Relationship quality was explored as a moderator.

Methods: $N = 338$ couples (target persons randomized) were randomly assigned to a dyadic-planning- (DPC), an individual-planning- (IPC), or a no-planning dyadic-control condition (CC). MVPA was objectively assessed four times across 52 weeks using accelerometry. Physical fitness and proposed mediators (individual action control, received behavior-specific support and control) were repeatedly assessed. Relationship quality was measured at baseline. Latent growth curve-, multi-level-, and manifest mediation models were fit.

Results: Across 52 weeks, MVPA of IPC and CC target persons increased. MVPA of DPC target persons remained stable, but those who reported high relationship quality increased their MVPA over time. DPC partners showed steeper increases in physical fitness when compared to IPC partners, but not CC partners. DPC partners' increases in physical fitness were mediated by received support from target persons.

Conclusions: The dyadic planning intervention showed non-beneficial effects for target persons' MVPA, but beneficial effects on their partners' fitness. These findings resemble evidence from the social support literature indicating more benefits for support providers than for recipients.

Trial registration: ClinicalTrials.gov identifier: NCT01963494.

1. Introduction

Promoting physical activity and physical fitness are central primary prevention strategies aiming to reduce risk for noncommunicable diseases (Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017; Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010). For health benefits in adults, international guidelines recommend a minimum of 150 min of moderate-to-vigorous physical activity (MVPA) throughout the week which refers to any activity with ≥ 3 metabolic equivalents of task (MET; World Health Organization WHO, 2018). The majority of adults worldwide do not adhere to these guidelines (World Health Organization WHO, 2018). To help people translate their good intentions into action and maintain their actions over time, individual action planning (Carraro & Gaudreau, 2013) and social support (Carr et al., 2019; Rhodes et al., 2017) may be incorporated as active components of interventions targeting adults' physical activity. *Dyadic action planning*, that is two persons (a target person and a planning partner) jointly planning a behavior to be carried out by one of them (the target person), combines shares of both proposed active ingredients in one dyadic action regulation strategy (Burkert, Scholz, Gralla, Roigas, & Knoll, 2011). Recently, Knoll et al. (2017) reported short-term effects of a dyadic planning intervention on target persons' and partners'

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* Corresponding author. Habelschwerdter Allee, 4514195, Berlin, Germany.
E-mail address: jan.keller@fu-berlin.de (J. Keller).

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everyday physical activity by examining data of the present couple randomized controlled trial (RCT) up to the 6-week follow-up (i.e., primary outcome time-frame). Whereas short-term analyses by Knoll et al. (2017) were focusing on adoption and short-term maintenance of physical activity, long-term analyses performed in the present study (i.e., up to the 52-weeks follow-up) would clarify the sustainability of intervention effects in terms of long-term physical activity maintenance (Kwasnicka, Dombrowski, White, & Sniehotta, 2016; Rhodes et al., 2017). Besides physical activity, physical fitness is another health-relevant outcome of physical activity-related interventions, which was not included in the study on short-term findings (Knoll et al., 2017) due to its slow-changing nature as a physiological measure (Warburton, Nicol, & Bredin, 2006; Warburton et al., 2010). However, in the present study, changes of physical fitness would be expected to be observable at a long-term follow up (i.e., 52 weeks). To summarize, in addition to target persons' and partners' objectively assessed MVPA, the present study investigates target persons' and partners' physical fitness. Furthermore, the role of proposed intervention mediators (i.e., action control, social support, and social control) are investigated and relationship quality is explored as a potential moderator (Martire, Schulz, Helgeson, Small, & Saghafi, 2010).

Individual planning (also referred to as implementation intentions; Gollwitzer, 1999) was shown to help bridging the intention-behavior gap regarding physical activity (Carraro & Gaudreau, 2013; Hagger & Luszczynska, 2014). It is defined as the prospective mental simulation of future situational cues (e.g., when, where) that are linked to a behavioral response (cf. Gollwitzer, 1999). In addition to individual planning, two dyadic forms of planning have been proposed. Collaborative planning (e.g., Prestwich et al., 2005) describes a process where both dyad members jointly form plans for their (predominantly) joint behavioral enactment. Dyadic planning, on the other hand, refers to jointly forming plans for the behavioral enactment of one dyad member, the target person, while the other person, the partner, provides planning assistance (Burkert et al., 2011). Extending the above reviewed rationale (Rhodes et al., 2017; Warburton et al., 2010) for the examination of long-term effects of dyadic planning, it may be assumed that the planning partner may act as a reminder and resource to fall back on when the target person's self-regulation becomes more difficult. To this end, findings from a correlative longitudinal study with men after prostate cancer surgery (Keller et al., 2015) suggested that associations of self-reported dyadic planning with patients' rehabilitative training tended to manifest later in the behavior change process.

Dyadic planning is also assumed to aid health behavior change by enhancing post-intentional individual and dyadic behavior-regulatory strategies that are often placed in the post-intentional or volitional behavior change process in cognitive behavior change models (Berli, Stadler, Inauen, & Scholz, 2016; Zhang, Zhang, Schwarzer, & Hagger, 2019). These strategies include individual action control as well as received behavior-specific support and control from the dyadic planning partner (Burkert et al., 2011; Knoll et al., 2017). Individual action control reflects awareness of standards, self-monitoring, and regulation efforts to achieve behavioral goals (Carver & Scheier, 2002; Sniehotta, Scholz, & Schwarzer, 2005). Used as an in-situ strategy to monitor and reduce discrepancies between intended and currently implemented behavior change, action control was shown to be positively related to the adoption and maintenance of physical activity (e.g., Sniehotta et al., 2005). Additionally, the partner's inclusion in the planning process is assumed to instigate behavior-specific social support that refers to the planning partner's provision of instrumental assistance in and emotional encouragement for behavior change (Burkert et al., 2011; Burkert, Knoll, Luszczynska, & Gralla, 2012). Social support provision is associated with better physical activity outcomes (e.g., Hohl et al., 2016). Another social exchange process assumed to mediate effects of dyadic planning on physical activity is social control from the partner (Burkert et al., 2011, 2012). As a result of their involvement in the dyadic planning process, partners may try to actively influence target persons by pressuring or reminding them to perform the behavior (Lewis & Rook, 1999). Social control encompasses positive and negative forms of interaction and can be a mixed blessing when it comes to health behavior change (e.g., Lewis & Butterfield, 2005). Earlier work by Burkert et al. (2011) investigating couples with prostate cancer patients striving to regularly perform rehabilitation exercises showed differential behavioral effects of social control after an individual versus a dyadic planning intervention.

In addition to bridging the target person's intention-behavior gap, dyadic planning may aid the planning partner's behavior change. For instance, behavioral transmission in dyads, specifically couples (Jackson, Steptoe, & Wardle, 2015; Pauly et al., 2020), is well documented and might propel dyadic planning partners to become more active. Furthermore, within-dyad reciprocity of social exchange processes, including dyadic planning and social support, may produce beneficial effects on planning partners' behavior (Knoll et al., 2017).

To date, evidence from RCTs on dyadic planning's effectiveness is limited (Benyamini, Ashery, & Shiloh, 2011; Buitenhuis, Tuinman, & Hagedoorn, in press; Burkert et al., 2011). Only one study, presenting short-term findings of the present RCT, investigated everyday physical activity as the outcome (Knoll et al., 2017). This study showed no differential increase in accelerometer-assessed physical activity in target persons of a dyadic planning condition, compared with target persons from an individual planning condition or a dyadic no-planning control condition (see supplementary material A for the study material). Exploratory moderator analyses indicated that target persons from the dyadic planning condition who reported low relationship quality showed a decrease in physical activity over 6 weeks after the intervention, whereas physical activity was stable among target persons reporting high relationship quality (Knoll et al., 2017). Partners from the dyadic planning condition showed an initial increase in vigorous activity up to the 1-week follow-up, and a decrease during the following 5 weeks. In target persons from the dyadic planning condition, proposed mediators, individual action control and received partner support, but not received partner control, increased as a result of the dyadic planning intervention. The same was true for dyadic planning partners' received support. However, for target persons and partners alike, proposed mediators of dyadic planning were largely unrelated to physical activity outcomes at the 6-week follow-up (Knoll et al., 2017).

1.1. Aims and hypotheses

In this study, 52-week follow-up data of the afore-described RCT (Knoll et al., 2017) are reported to examine whether a dyadic planning intervention predicts long-term increases in MVPA. In addition to a lab-based intervention session at 1 week post-baseline, the RCT also included a booster intervention at the 20-weeks follow-up that was not subject of the previous report (Knoll et al., 2017). Moreover, accelerometer-assessed MVPA, the primary outcome, was complemented by an objectively measured physical health indicator, physical fitness (Warburton et al., 2010).

Regarding changes in accelerometer-assessed MVPA (Hypothesis 1a) and physical fitness (Hypothesis 1b) over the course of 52 weeks, highest increases were expected for target persons who took part in a dyadic planning condition (DPC) compared to target persons from an individual planning condition (IPC) or a no-planning dyadic control condition (CC). Furthermore, highest increases in MVPA (Hypothesis 2a) and physical fitness (Hypothesis 2b) over 12 months were expected for partners of the DPC when compared to IPC and CC partners. Dyadic planning intervention effects on target persons' MVPA (Hypothesis 3a) and physical fitness (Hypothesis 3b) as well as partners' MVPA (Hypothesis 4a) and physical fitness (Hypothesis 4b) were assumed to be mediated by individual action control, received physical activity-specific support, and received physical activity-specific control from the other partner. Following up short-term findings reported by Knoll et al. (2017) and adhering to recommendations by Martire et al. (2010), baseline relationship quality was explored as a moderator of direct intervention effects on MVPA and physical fitness outcomes.

2. Method

2.1. Design and procedure

Following informed-consent procedures, couples responded to the baseline (Time [T]0) questionnaire in the lab and performed a 2 km walking test (i.e., to assess physical fitness) which was followed by a 1-week baseline accelerometry assessment (see supplementary materials B, Figure 1, for the study design). Subsequently, couples returned to the lab (T1; approx. 1 week following T0), received a general motivation treatment and were randomly assigned to roles of target persons and partners as well as to 1 of 3 intervention arms. The lab-based intervention session took place at T1, followed by a booster intervention, which was conducted by couples in their homes at T5 (20 weeks following T1). Further 1-week physical activity assessments (by accelerometers) took place at 1 week (T2), 6 weeks (T3), and 52 weeks (T7) following T1. Physical fitness was measured again at T7. Self-reported dyadic planning and proposed mediators were assessed with questionnaires at baseline (T0), 1 week (T2), 6 weeks (T3), 19 weeks (T4), 26 weeks (T6), and 52 weeks (T7) following T1. Relationship quality was assessed at baseline. The study was registered at clinicaltrials.gov (NCT01963494). To compensate travel costs and time spent working on the study tasks, couples received €287.70 for full participation in the trial. The institutional review board at the first author's institution approved the study.

2.2. Sample and recruitment

$N = 346$ healthy, adult, heterosexual, and cohabiting couples from the metropolitan area of Berlin, Germany, were enrolled. Inclusion and exclusion criteria are reported in the supplementary materials B. The recruitment approach included mostly reactive strategies such as advertisements in newspapers, social media, or worksite intranets (Knoll et al., 2017). Data were collected between March 2013 and December 2016. Of $n = 338$ couples randomized to conditions, $n = 269$ couples provided data at T7 (79.6%; see supplementary materials B, Figure 2, for the sample flow). Target persons' (49.4% female) mean age was 37.74 years ($SD = 15.59$; range: 19-80), partners' (49.4% male) mean age was 38.33 years ($SD = 15.65$; range: 18-79). Most target persons (76.6%) and partners (73.4%) reported a high school education and about half of target persons (44.0%) and partners (46.4%) reported a university degree. According to target persons' reports, mean relationship duration was 11.36 years ($SD = 12.61$) (see supplementary materials B, Table 1, for further sample characteristics).

2.3. Randomization

Randomization procedures were conducted using computer-generated lists of random numbers. In a first step, both couple members were randomly assigned to the roles of target person or partner. The second randomization step included a random assignment of couples to 1 of the 3 conditions by using stratified randomization in blocks of six for each stratum (male or female target person).

2.4. Intervention

At T1, couples came to the lab and participated in a *motivation treatment* that aimed at promoting all participants' intention to increase MVPA (for further information, see Knoll et al., 2017). Next, following randomization, the *lab-based main intervention* was delivered by study personnel who provided the study material and assisted participants when questions arose. Study material of the DPC, IPC, and CC were parallel in structure, but differed in content (see supplementary material A). At T5 (booster intervention), the same study material was completed by participants in their homes, without supervision by study personnel. Particpating couples were instructed to work on the booster intervention when they would not be distracted and asked to return materials via mail using pre-stamped envelopes.

DPC. Target persons and partners were asked to jointly form 5 physical activity plans for the target person. For each plan, couples were asked to discuss and decide 'when', 'where', and 'how' the target person would become physically active and structure the plan using a "when/if-then" format. Next, target persons wrote these plans on a dyadic planning sheet, while partners used protocol sheets to take notes on the planning discussion. Target persons were instructed to imagine themselves in the planned situations enacting their planned physical activity and couples were asked to continue dyadic planning in their daily lives.

IPC. Target persons and partners were invited to separate rooms and asked to work on an individual planning sheet (target person) or a stone sculpture interpretation task (partner). The individual planning sheet was analogous to the DPC condition, but did not include the partner's involvement. In the stone sculpture interpretation task, partners were asked to provide up to 5 interpretations of the meaning of a stone sculpture depicted in a photograph and write down the interpretation on provided sheets.

CC. Target persons and partners were instructed to work jointly on the stone sculpture interpretation task, analogous to the partner's task in the IPC. The interaction between both partners was structured in a manner analogous to the DPC to control for potential effects of mere partner collaboration. Specifically, both partners were asked to discuss the meaning of the stone sculpture followed by target persons' documenting up to 5 interpretations on a sheet and partners taking notes of the discussion.

In the DPC and IPC, the following behavior change techniques (BCTs; Michie et al., 2013) were used: BCT 1.4 ("action planning"; DPC, IPC), BCT 15.2 ("mental rehearsal of successful performance"; DPC, IPC), and BCT 3.2 ("social support"; DPC). The study materials and study design were based on prior work (Burkert et al., 2011) and recommendations on couple-oriented interventions (Martire et al., 2010).

2.5. Measures

Moderate-to-vigorous physical activity (MVPA). MVPA was assessed using triaxial accelerometers (ActiGraph GT3X, Pensacola, FL). At T0, T2, T3, and T7, participants were instructed to wear the accelerometer on their right hip during waking hours for 7 consecutive days. Valid wear times were assessment periods in which the accelerometer was worn on at least 4 days for at least 10 h per day (i.e., valid wear day). Using the algorithm by Sasaki, John, and Freedson (2011) for each valid wear day, daily minutes of MVPA were computed with a sum score of minutes with at least 6167 counts per minute (i.e., at least moderate intensity of movement). Univariate outliers ($z > |3.29|$) were winsorized to 1 unit lower/higher than the next highest/lowest value in the distribution (Tabachnick & Fidell, 2007).

Physical fitness. At T0 and T7, participants' physical fitness was assessed with a 2 km walking test (Boes, 2003; Oja, Laukkanen, Pasanen, Tyry, & Vuori, 1991). Couples were asked to walk as fast as possible (but not run or jog), without risking their health. An indoor flat venue was used for the test. Based on participants' age, sex, body mass index (BMI), test duration, and heart-rate after finishing the 2 km distance, a physical fitness parameter was computed. The physical fitness parameter was not computed for participants ($n = 58$) with anti-hypertensive medication as this interferes with the heart-rate measure (Boes, 2003). Univariate outliers ($z > |3.29|$) were winsorized.

Self-reported dyadic planning and hypothesized mediators. Self-reported dyadic planning and the hypothesized mediators were measured in target persons and partners at T0, T2, T3, T4, T6, and T7 using a response format ranging from 1 = "does not apply at all" to

6 = “applies exactly”. Participants were instructed to refer to the past 7 days.

Self-reported *dyadic planning* was measured with 4 items with the stem “I have made a detailed plan together with my partner regarding …” (Burkert et al., 2011) followed by (a) “when,” (b) “where,” (c) “how,” and (d) “how often to be physically active”. Both target persons and partners responded to the items referring to the planning *of their own* physical activity. Cronbach’s alphas ranged between α = .92 and α = .98.

Adapting items used by Sniehotta et al. (2005), *individual action control* was measured with 8 items covering subfacets awareness of standards, self-monitoring, and self-regulatory effort. A sample item read: “During the past 7 days, I have really tried to be regularly physically active”. Internal consistencies ranged from α = .84 to α = .95.

Adapted from a study by Burkert et al. (2011), *received partner support* was assessed by 6 items (e.g., “My partner helped me to be physically active”) representing one partner’s receipt of assistance in and encouragement for physical activity from the other partner. Cronbach’s alphas ranged between α = .80 and α = .92.

Received partner control reflects the attempt of one partner to actively influence the other partner to be physically active. Adapting items by Lewis and Rook (1999), received partner control was assessed with 3 items (e.g., “My partner pressured me to be physically active”). Internal consistencies ranged from α = .79 to α = .94.

Relationship quality and covariates. The German 12-item short form of the Dyadic Adjustment Scale (Dinkel & Balck, 2006) was used to assess *relationship quality* of target persons and partners at T0. Internal consistencies were α = .79 for target persons and α = .85 for partners. As covariates, participants’ sex (0 = women; 1 = men), age, and daily accelerometer wear time (for models predicting MVPA) were measured. Further covariates which were assessed and included in statistical models based on results from the randomization check were target persons’ BMI at T0, and partners’ reports on having children at T0 (yes = 1, no = 0).

2.6. Analyses

Data were analyzed for target persons and partners separately, using IBM SPSS 25 und Mplus 7 (Muthén & Muthén, 1998-2012). Attrition analyses were performed using χ^2 tests or t tests followed by logistic regressions. Randomization checks were conducted applying multivariate analyses of variance with Bonferroni post-hoc tests and logistic regressions. Manipulation checks were performed using multiple regression models with self-reported dyadic planning as the outcome.

To investigate long-term intervention effects on MVPA and physical fitness, latent growth curve models (LGCM; Duncan, Duncan, & Strycker, 2013) for continuous outcomes were fit with Mplus. Manifest indicators of intercept and slope were MVPA levels at T0, T2, T3, and T7 for MVPA models or physical fitness at T0 and T7 for fitness models. To examine between-group differences, conditions were dummy coded and DPC was used as a reference. IPC and CC (vs. DPC as reference) were modelled as predictors of the intercept and linear slope. The intercept was modelled at T7 to directly determine between-group differences at the 52-week follow-up. The linear slope reflected the weekly time trend between week 1 and week 52 following the lab-based intervention at T1. Unless dichotomous, covariates were grand-mean centered. Covariates were modelled as time-invariant (i.e., T0 covariates) predictors of the intercept or time-variant (i.e., accelerometer wear time in MVPA models) predictors of the indicators. Controlling for covariates, unstandardized intercept coefficients represented mean differences between conditions at T7 and unstandardized slope coefficients represented mean group differences in change in MVPA or physical fitness.

Mediation hypotheses were tested using manifest mediation models in Mplus predicting T7 MVPA or T7 physical fitness as the outcome and using individual action control, received partner support, and partner control as mediators between dummy-coded group variables and the outcome (effects of the mediators at different measurement points were tested: T2, T3, T4, and T6; see supplementary materials B, Table 2). Baseline levels of the outcome and the mediators and covariates were accounted for in all mediation models. Bias-corrected bootstrapping (BC) with 5000 resamples was applied and indirect effects for the 97.5% confidence interval (CI_{BC}) were calculated (MacKinnon, Lockwood, & Williams, 2004).

Concerning the moderator and simple slope analyses with baseline relationship quality, LGCMs yielded a negative variance covariance matrix. Instead of LGCM, we conducted analogous linear mixed models in SPSS (measurement points in time nested within individuals) with a linear time trend centered at T7. Relationship quality, all 2- and 3-way interaction terms with the linear time trend, dummy-coded conditions IPC and CC (vs. DPC as reference), and covariates were included as predictors of MVPA or physical fitness. Because our focus was on the DPC, when a significant condition x time x relationship quality interaction emerged, analyses were repeated within this condition only. When evidence of a time x relationship quality interaction emerged in analyses within the DPC, this was followed up by simple slope analyses. All random effects were tested, but retained only when models converged (Barr, Levy, Scheepers, & Tily, 2013). To keep all available data in the analyses, a full information maximum likelihood procedure was used.

3. Results

3.1. Attrition analyses and randomization check

Couples who dropped out before T7 were similar to couples from the longitudinal sample in most key variables. However, in couples who dropped out target persons were younger (t(116.47) = 2.11, p = .037; d = .27), reported T0 injuries more often (χ^2(1) = 8.199, p = .004; d = .32), were more likely to smoke cigarettes at T0 (χ^2(1) = 3.896, p = .048; d = .22), reported lower physical activity intentions at T0 (t(335) = 3.02, p = .003; d = .39), and lower received partner control at T0 (t(127.98) = 2.52, p = .013; d = .32).

Results of randomization checks indicated no between-condition differences for most variables under study, except for target persons’ BMI (higher in the DPC than in the CC; Bonferroni: M_{diff} = 1.82, SE = 0.57, p = .005, d = .45) and partners’ report on having children (more frequent in the IPC than in the CC; B = .55, SE = 0.28, p = .047, d = .30) (cf. Knoll et al., 2017). Both variables were covariates in respective target person or partner models.

3.2. Treatment duration, treatment integrity, and manipulation checks

As reported previously (Knoll et al., 2017), the duration of the planning or control procedures at the lab-based intervention was on average 5-6 min longer in the DPC and CC, compared to the IPC. A total of n = 102 (92%) couples from the DPC, n = 109 (96%) couples from the IPC, and n = 105 (93%) couples from the CC returned the booster material. The booster intervention duration was about 7 min longer in the DPC (M = 27.05 min, SD = 13.22) and the CC (M = 27.34 min, SD = 11.01) than in the IPC (M = 20.04 min, SD = 10.33; IPC vs. DPC, Bonferroni: M_{diff} = 7.01, SE = 1.69, p < .001, d = .59; IPC vs. CC, Bonferroni: M_{diff} = 7.29, SE = 1.68, p < .001, d = .68). Across all conditions, most participants created 5 plans or 5 sculpture interpretations at the lab-based intervention (93%) and at the booster intervention (90%).

Manipulation checks revealed that intentions of target persons and partners showed overall increases following the motivation treatment. Furthermore, DPC target persons (vs. IPC, CC) and DPC partners (vs. IPC) showed steeper increases in self-reported dyadic planning at 1 week, followed by decreases up to 6 weeks following the lab-based intervention (cf. Knoll et al., 2017). However, following the booster

Table 1
Descriptive Statistics and Internal Consistency for Study Variables.

		Dyadic planning condition (n = 111)		Individual planning condition (n = 114)		Control condition (n = 113)	
		Target person	Partner	Target person	Partner	Target person	Partner
		M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Moderate-to-vigorous physical activity [min/day]	T0	63.50 (28.34)	60.57 (27.68)	59.76 (25.72)	63.15 (26.98)	62.03 (26.22)	59.85 (27.08)
	T2	65.41 (28.58)	62.39 (27.20)	60.16 (26.95)	58.57 (26.86)	61.96 (24.14)	61.32 (25.44)
	T3	57.24 (26.09)	59.56 (28.75)	58.10 (25.48)	57.97 (30.48)	57.82 (25.60)	59.07 (25.90)
	T7	63.61 (28.65)	68.84 (26.11)	68.26 (34.79)	71.01 (34.40)	73.80 (35.77)	63.82 (31.13)
ICC		.71	.58	.52	.61	.56	.51
Physical fitness	T0	86.31 (18.72)	90.88 (19.32)	93.01 (16.62)	91.89 (18.45)	95.39 (16.76)	93.66 (17.07)
	T7	87.40 (21.26)	93.46 (20.08)	94.43 (17.39)	92.79 (17.84)	96.75 (17.01)	96.35 (15.67)
ICC		.79	.73	.86	.91	.88	.85
Dyadic planning [1-6]	T0	2.45 (1.58)	2.38 (1.63)	2.57 (1.53)	2.76 (1.62)	2.73 (1.54)	2.70 (1.57)
	T2	4.03 (1.67)	2.78 (1.60)	2.76 (1.38)	2.67 (1.52)	2.66 (1.54)	2.68 (1.59)
	T3	2.74 (1.53)	2.56 (1.60)	2.58 (1.57)	2.48 (1.46)	2.65 (1.66)	2.64 (1.61)
	T4	2.26 (1.43)	2.13 (1.44)	2.29 (1.41)	2.35 (1.58)	2.40 (1.50)	2.45 (1.58)
	T6	2.27 (1.50)	2.34 (1.56)	2.44 (1.50)	2.38 (1.32)	2.33 (1.49)	2.36 (1.40)
	T7	2.17 (1.31)	2.25 (1.49)	2.42 (1.50)	2.55 (1.46)	2.73 (1.64)	2.77 (1.48)
Cronbach's α		.947–.973	.956–.976	.932–.963	.941–.972	.916–.967	.939–.974
ICC		.19	.34	.37	.39	.41	.45
Individual action control [1-6]	T0	2.82 (1.03)	2.84 (1.22)	2.92 (1.31)	3.17 (1.18)	2.99 (1.23)	3.18 (1.28)
	T2	3.70 (1.02)	3.25 (1.14)	3.57 (1.09)	3.51 (1.10)	3.27 (1.27)	3.32 (1.26)
	T3	3.30 (1.01)	3.04 (1.33)	3.22 (1.17)	3.41 (1.25)	2.96 (1.12)	3.21 (1.34)
	T4	3.07 (1.15)	2.98 (1.28)	3.04 (1.18)	3.16 (1.31)	2.86 (1.22)	3.18 (1.35)
	T6	3.10 (1.08)	3.07 (1.27)	3.11 (1.18)	3.13 (1.25)	2.88 (1.16)	3.22 (1.22)
	T7	3.11 (1.27)	3.29 (1.15)	3.23 (1.23)	3.30 (1.13)	3.07 (1.11)	3.30 (1.40)
Cronbach's α		.844–.927	.881–.938	.903–.922	.885–.942	.885–.921	.921–.945
ICCv		.36	.51	.38	.51	.49	.63
Received partner support [1-6]	T0	2.50 (1.21)	2.45 (1.28)	2.77 (1.30)	2.79 (1.35)	2.59 (1.12)	2.70 (1.20)
	T2	3.03 (1.23)	2.80 (1.24)	2.73 (1.09)	2.61 (1.16)	2.65 (1.26)	2.68 (1.16)
	T3	2.81 (1.35)	2.65 (1.32)	2.70 (1.23)	2.50 (1.25)	2.54 (1.31)	2.71 (1.35)
	T4	2.55 (1.24)	2.40 (1.28)	2.53 (1.22)	2.45 (1.26)	2.44 (1.28)	2.47 (1.38)
	T6	2.47 (1.27)	2.46 (1.25)	2.60 (1.23)	2.42 (1.25)	2.46 (1.23)	2.49 (1.31)
	T7	2.50 (1.32)	2.59 (1.26)	2.60 (1.21)	2.53 (1.28)	2.67 (1.14)	2.67 (1.35)
Cronbach's α		.824–.921	.841–.878	.810–.869	.856–.895	.800–.882	.800–.912
ICC		.50	.54	.52	.42	.57	.56
Received partner control [1-6]	T0	1.99 (1.41)	1.72 (1.20)	1.98 (1.14)	1.79 (1.25)	1.92 (1.20)	2.05 (1.28)
	T2	1.89 (1.07)	1.86 (1.09)	1.82 (1.08)	1.83 (1.07)	1.76 (1.14)	1.94 (1.17)
	T3	1.77 (1.17)	1.79 (1.22)	1.73 (1.16)	1.80 (1.16)	1.75 (1.14)	1.78 (1.22)
	T4	1.72 (1.09)	1.82 (1.19)	1.72 (1.04)	1.85 (1.19)	1.69 (1.13)	1.76 (1.17)
	T6	1.75 (1.13)	1.69 (1.02)	1.63 (1.03)	1.86 (1.18)	1.66 (1.11)	1.81 (1.08)
	T7	1.70 (1.03)	1.75 (1.11)	1.85 (1.20)	1.96 (1.31)	1.79 (1.17)	1.82 (1.17)
Cronbach's α		.788–.924	.793–.918	.806–.926	.905–.941	.848–.925	.860–.940
ICC		.47	.51	.54	.57	.63	.57

Note. $232 \leq n \leq 338$ target persons and $243 \leq n \leq 338$ partners due to missing values and dropout. M: Mean. SD: Standard deviation. ICC: Intra-class correlation coefficient. [1-6] refers to the response scale of the variable.

intervention, there were no between-group differences in self-reported dyadic planning among target persons and partners (Table 1; partners completed dyadic planning items referring to the planning of their own physical activity).

3.3. Effects of dyadic planning on MVPA and physical fitness

Descriptive statistics for target persons, partners, and conditions are displayed in Table 1. MVPA developments over time are depicted in the supplementary materials B (Figure 3).

LGCM models testing direct intervention effects yielded acceptable (target persons) and good (partners) fit indices (Table 2). Contrary to H1a, both target persons of the IPC and CC showed significantly larger MVPA improvements over 52 weeks than target persons of the DPC who did not change their MVPA levels (slope coefficients in Table 2). Significantly higher MVPA means at T7 for CC than for DPC target persons were observed, whereas mean T7 differences between IPC and DPC were non-significant (intercept coefficients in Table 2). When IPC target persons were compared with CC target persons as the reference, there were no differences in MVPA changes over time (Est. [SE] = −0.05 min/week [0.08], p = .501) and MVPA means at T7 (Est. [SE] = −3.19 min [4.69], p = .497). Contrary to H1b, physical fitness did not change for target persons of any experimental condition (e.g., DPC slope coefficient in Table 2). Nevertheless, relatively stable differences in levels (non-significant at T0, however) yielded significantly higher T7 means of physical fitness for IPC and CC, compared to DPC target persons (intercept coefficients in Table 2).

Not supporting H2a, DPC partners showed a linear increase in MVPA which did not significantly differ from a linear increase in MVPA observed among IPC or CC partners. No mean differences between conditions were observed at T7 (Table 2). Partially supporting H2b, DPC partners' physical fitness increased significantly and did so more strongly than in IPC partners. However, no slope differences were found when DPC and CC partners were compared. Again, no mean differences at T7 were found (Table 2).

3.4. Mediation models

Results from preliminary analyses (supplementary materials B, Table 2) were used to inform an empirical decision on the choice of the measurement point of the proposed mediators to be included in models. To preserve the temporal order among predictors, mediators, and outcomes in the final models, T2, T3, T4, and T6 measurements of the mediators were analyzed. For target persons at T2, we found that the

Table 2
Latent Growth Curve Models Findings: Target Persons' and Partners' Moderate-to-vigorous Physical Activity and Physical Fitness with the Intercept Modelled at the 52-Weeks Follow-up (the Dyadic Planning Condition as the Reference Group).

	Moderate-to-vigorous physical activity (MVPA)		Physical fitness	
Target persons				
Fixed effects	*Estimate* (*SE*)	*p*	*Estimate* (*SE*)	*p*
Intercept (DPC)	58.39 (3.70)	<.001	88.49 (1.73)	<.001
Intercept (IPC vs. DPC)	7.01 (4.72)	.138	4.56 (2.15)	.034
Intercept (CC vs. DPC)	10.20 (4.84)	.035	5.27 (2.18)	.016
Slope (DPC)	−0.02 (0.06)	.770	−0.01 (0.02)	.663
Slope (IPC vs. DPC)	0.19 (0.08)	.012	0.02 (0.03)	.475
Slope (CC vs. DPC)	0.24 (0.08)	.002	0.04 (0.03)	.222
Random effects	Variance (*SE*)	Covariance (*SE*)	Variance (*SE*)	Covariance (*SE*)
Intercept	696.15 (1098.89)	4.15 (21.12), $p = .844$	195.94 (18.06)	1.42 (0.20), $p < .001$
Slope	0.05 (0.41)		0.04 (0.00)	
Model fit	$\chi^2(52) = 92.41$, $p = .001$, TLI = 0.94, RMSEA = .05		$\chi^2(11) = 46.36$, $p < .001$, TLI = 0.93, RMSEA = .10	
Partners				
Fixed effects	*Estimate* (*SE*)	*p*	*Estimate* (*SE*)	*p*
Intercept (DPC)	68.34 (3.90)	<.001	97.73 (2.39)	<.001
Intercept (IPC vs. DPC)	2.52 (4.64)	.586	−1.95 (2.55)	.446
Intercept (CC vs. DPC)	−4.43 (4.70)	.346	1.10 (2.61)	.674
Slope (DPC)	0.14 (0.06)	.024	0.07 (0.02)	.001
Slope (IPC vs. DPC)	0.06 (0.08)	.466	−0.07 (0.03)	.019
Slope (CC vs. DPC)	−0.06 (0.08)	.478	−0.04 (0.03)	.243
Random effects	Variance (*SE*)	Covariance (*SE*)	Variance (*SE*)	Covariance (*SE*)
Intercept	390.23 (1089.00)	0.01 (20.96), $p = 1.000$	312.42 (26.86)	0.88 (0.23), $p < .001$
Slope	0.04 (0.40)		0.04 (0.00)	
Model fit	$\chi^2(50) = 63.27$, $p = .099$, TLI = 0.98, RMSEA = .03		$\chi^2(10) = 15.40$, $p = .118$, TLI = 0.98, RMSEA = .04	

Note. $n = 338$ target persons and $n = 338$ partners. DCP: dyadic planning condition. IPC: individual planning condition. CC: control condition. SE: standard error. Slope: linear trend over the course of 52 weeks. Intercept modelled at the 52-weeks follow-up. TLI: Tucker Lewis index, RMSEA: Root mean square error of approximation. Controlled for age, gender, accelerometer wear time (only in MVPA models), body mass index (only in target person models), and having children (only in partner models). Covariances between indicators and residual variances of indicators not displayed.

DPC and IPC were positively associated with action control when compared with the CC, but a non-significant difference was found when DPC and ICP were contrasted. For target persons and partners alike, the DPC was positively related with received support, but again only at T2, whereas associations became weaker, non-significant, and less consistent over time. None of the associations between the experimental condition and received control were significant. Moreover, the booster intervention (T5) had no effects on the proposed mediators. Manifest path models for target persons and partners testing mediation hypotheses thus included T2 assessments of proposed mediators (controlled for T0) and yielded acceptable and good model fit indices (supplementary materials B, Tables 3 and 4).

Results from models predicting *target persons'* MVPA (H3a) and physical fitness (H3b) indicated non-significant relationships between T2 mediators and T7 outcomes, except for a marginal negative link ($p = .083$) between received control and physical fitness. Thus, in contrast to H3a nor H3b, none of the indirect effects between conditions and outcomes via T2 mediators were significant in target person models (supplementary materials B, Table 3).

Path models predicting *partners'* MVPA (H4a) and physical fitness (H4b; Figure 1; supplementary materials B, Table 4) indicated a significant relationship of T2 partners' reports of received support with T7 partners' physical fitness, but not with T7 partners' MVPA (not in line with H4a). As DPC partners received more T2 support, when compared to CC and IPC partners, two significant indirect effects emerged, partially supporting H4b: (1) from DPC (vs. CC) to T7 physical fitness, via T2 partner-received support, ($B = 0.39$; $SE = 0.32$; 95% $CI_{BC} = 0.001$ to 1.344) and (2) from DPC (vs. IPC) to T7 physical fitness, via T2 partners' reports of received support ($B = 0.47$; $SE = 0.35$; 95% $CI_{BC} = 0.025$ to 1.527).

3.5. Intervention effects moderated by relationship quality

A significant CC (vs. DPC as reference) x time x relationship quality interaction emerged for target persons' MVPA (supplementary materials B, Table 5). Simple slope analyses (at $M \pm 1$ *SD* of the moderator) of a time x relationship quality interaction within the DPC indicated that while target persons with lower relationship quality showed stable MVPA levels, MVPA of target persons with higher relationship quality increased significantly over time (supplementary materials B, Table 5 and Figure 4). Regarding intervention effects on DPC partners' MVPA (supplementary materials B, Table 5) and DPC target persons' and partners' physical fitness, no moderating role of relationship quality was found.

4. Discussion

In this study, healthy couples were followed up for 52 weeks to evaluate the effects of a dyadic planning condition (DPC) compared to effects of an individual planning condition (IPC) and a no-planning dyadic control condition (CC) on target persons' and partners' MVPA and physical fitness. Experimental conditions consisted of the lab-based intervention session and a home-based booster session, conducted 20 weeks following the intervention in the lab. Whereas the lab-based intervention session had passed manipulation checks (Knoll et al., 2017), the booster did not result in a further increase of couples' self-reported dyadic planning.

Prior findings from this RCT showed no between-condition differences in terms of changes in target persons' physical activity up to the primary endpoint at 6 weeks following the lab-based intervention session (Knoll et al., 2017). At the 52-weeks follow-up, while the DCP had no effect on target persons' MVPA, target persons from IPC and CC managed to increase their MVPA over time. Contrary to our hypotheses, participating in the DPC seemed to impede an otherwise general increase in MVPA in target persons, motivated to become more physically active. Moreover, partners from all conditions, including DPC partners – none of whom were directly targeted by active intervention procedures – increased their MVPA across 52 weeks. These findings show that the dyadic planning intervention resulted in distinct effects on target persons and their partners.

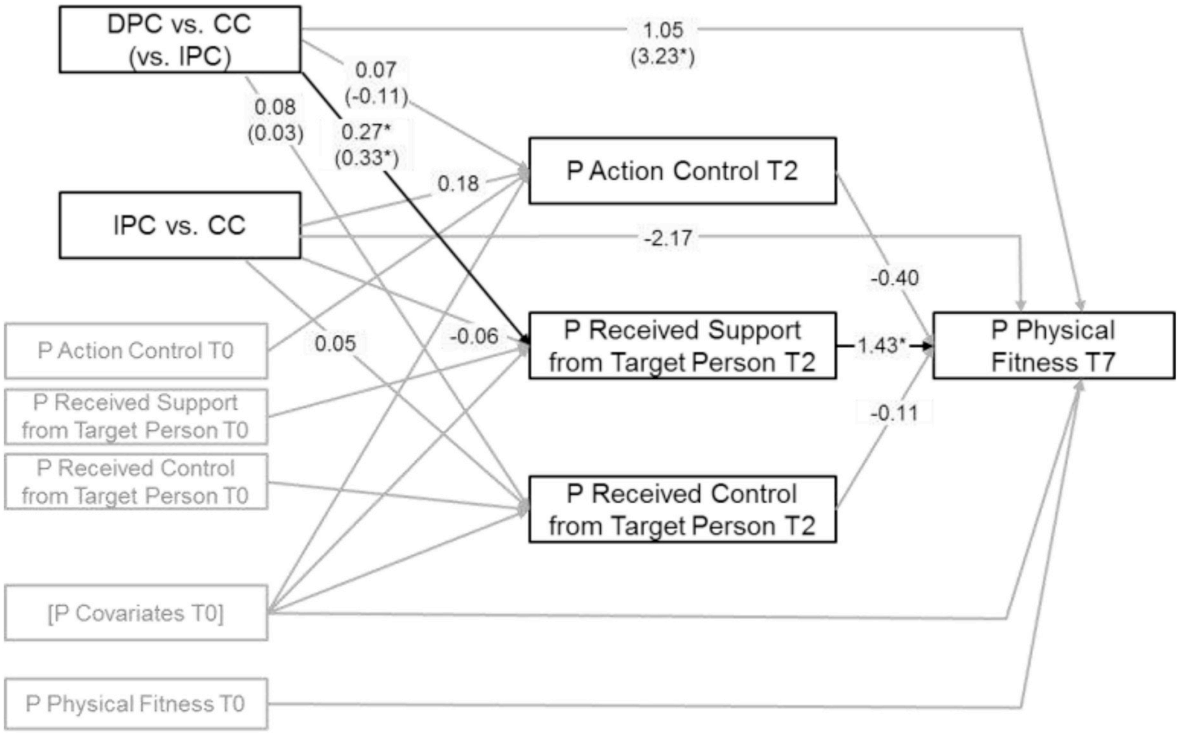

Fig. 1. Mediation model of intervention effects and proposed mediators (T2) on partners' physical fitness at the 52-week follow-up. Note. $n = 338$ partners. Unstandardized coefficients. P: partner variable. T: time. DPC: dyadic planning condition. IPC: individual planning condition. CC: control condition. Coefficients in brackets refer to a separate, but analogous model with IPC as the reference group. Covariances among predictors and mediators, covariances among residuals, residuals themselves, and coefficients of paths in grey are not depicted. Model fit: $\chi^2(20) = 36.01$, $p = .015$, CFI = 0.98, TLI = 0.94, RMSEA = .05. $^*p < .05$.

In terms of general MVPA improvements of the IPC and CC, similar results were found by Winett et al. (2011) who also examined long-term effects on objective physical activity. Regarding weight loss as the outcome, the study by Knäuper et al. (2018) also reports long-term improvements of both an individual planning intervention condition and the active control condition. Possibly, participants' baseline motivation to increase their everyday physical activity and take part in a complex couple trial may have triggered a long-term goal pursuit.

But why would the DPC not benefit MVPA for target persons? In the short run, dyadic planning was positively and mostly differentially (i.e., between-condition differences) associated with other potentially helpful intervention mechanisms, including action control (Sniehotta et al., 2005) and behavior-specific support (Hohl et al., 2016) in target persons. However, neither of the proposed mediators, including social control that was unaffected by the intervention, were related with MVPA at the 52-week follow up. Furthermore, a similar picture emerged in target persons' short-term mediation models, using physical activity outcomes at the 6-week follow-up (Knoll et al., 2017). We believe that although they were unrelated to any of the DPC target persons' outcomes, insights may nevertheless come from these mediators themselves; particularly, from a relatively strong differential increase of action control in DPC target persons (at T2) following the lab-based intervention session. The set-up of the DPC casted partners in the role of "supportive spectators" to the behavior change process, likely increasing target persons' need to very closely monitor their successive attempts to become more active. This might have – inadvertently – put target persons on the spot for success to a degree that was non-productive for many, specifically for those who had reported poorer relationship quality (discussed below). An earlier RCT examining couples (Burkert et al., 2011) also led to differential increases in action control in tumor patients following a dyadic planning intervention to increase rehabilitative exercises, albeit there, the increase of action control appeared to be beneficial. Nevertheless, the present increase in action control may predominantly indicate an increase in self-focused attention, and in this case likely public self-focus (Carver & Scheier, 1987). Public self-focus is defined as reflections on one's own goals and behaviors "in which the needs, desires, or reactions of others are acknowledged and taken into account" (Carver & Scheier, 1987, p. 527). For target persons of the DPC, the public self-focus may have compromised an otherwise high motivation to become more active, for instance, via increases of negative affect (Mor & Winquist, 2002). Likewise, further support from the dyadic planning partner might have created additional costs to DPC target-persons' self-esteem (e.g., Fisher, Nadler, & Whitcher-Alagna, 1982). Future work should account for additional mechanisms, such as public self-focus or self-esteem, to better account for the potential costs of dyadic planning.

Similar to short-term findings of this RCT (Knoll et al., 2017), relationship quality moderated intervention effects on MVPA in DPC target persons, but not in DCP partners. DPC target persons who had reported high relationship quality increased their MVPA over 52 weeks, but those with lower relationship quality did not. This suggests that relationship quality enhanced the otherwise non-beneficial long-term effects of the DPC on MVPA, possibly via buffering the impact of the inadvertently placed spectator effect. The consistently observed moderation of relationship quality underscores recommendations from the couple intervention literature to routinely take into account couples' relationship functioning (Arden-Close & McGrath, 2017; Martire et al., 2010).

Findings regarding physical fitness as a long-term outcome yielded partial support for hypotheses concerning partners, but not for target persons. This pattern of results is similar to short-term findings, where DPC partners, but not DCP target persons emerged with direct beneficial, albeit small and short-lived effects of the intervention on vigorous activity (Knoll et al., 2017). In the present study, DPC and CC partners showed similar increases in physical fitness that were larger than those of ICP partners. Additionally, only among DPC partners, this direct effect was mediated via early (i.e., 1 week following the lab-based intervention) reports of support received from target persons.

DPC partners' plan assistance during and shortly after the lab-based main intervention was likely reciprocated by target persons in form of enhanced dyadic planning of partners' physical activity and enhanced supportive interaction, benefiting partners (Knoll et al., 2017). These early dynamics may have presented a means to prolong indirect beneficial effects for DPC partners, who were less on the spot for success than target persons and might thus have derived a net benefit from social exchange processes instigated by the DPC, if not in terms of their MVPA, then at least in terms of their physical fitness.

Considering the sum of apparent, albeit small, short-term and long-term benefits of the DPC for partners, their randomly assigned role of *plan-related support provider* in the DPC might have put them in a less compromising position than target persons who were assigned the role of *plan-related support recipients* and put on the spot for success. In all, these findings resemble evidence on positive effects of support provision not only on providers' own well-being (Kroemeke, Knoll, & Sobczyk-Kruszelnicka, 2019), but also on their health behavior (Berli, Bolger, Shrout, Stadler, & Scholz, 2018).

4.1. Limitations, outlook, and conclusion

Despite strengths of the study including the assessment of both partners' perspectives, the objective measurement of study outcomes as well as the controlled testing of intervention components (Arden-Close & McGrath, 2017), some limitations have to be considered and amended by future research. First, participants were relatively active from the start. For individuals with higher baseline physical activity (vs. those with lower), planning intervention effects are often not superior to control condition effects (e.g., Carraro & Gaudreau, 2013; Winett et al., 2011). Future studies should attempt to recruit individuals who are particularly in need to increase their physical activity. Second, the present couple study focused on primary prevention, namely physical activity promotion in a healthy population. In dyadic planning, two dyad members are assigned to distinct roles, thus, interventions might be more effective in couple contexts in which partners naturally act in distinct roles, with one partner potentially more in need for behavior change than the other (e.g., patient-caregiver contexts; Burkert et al., 2011). Third and relatedly, this trial featured a highly controlled study design, with participants randomly assigned to only one study role (i.e., target person as the recipient and partner as the provider). Randomly assigned roles might have counteracted some couples' preferred behavior-specific support dynamics and inadvertently contributed to the set of non-findings for DPC target persons. In future research on dyadic planning study roles might be switched after the initial round of planning which would enhance partners' equity (Kuijer, Buunk, De Jong, Ybema, & Sanderman, 2004) and provide both partners with the (assigned) opportunity to act as providers (Kroemeke et al., 2019). Fourth, to learn more about mechanisms of dyadic planning interventions, open-ended qualitative questions should be added, for instance to ask for information on the exact nature of action control and supportive interactions in couples. Fifth, the time gaps between the lab-based intervention and the booster (i.e., 20 weeks after the lab-based intervention) as well as between the booster and the last measurement point (i.e., 32 weeks for the behavioral outcome) were long which could limit the additive effect of the booster. Multiple booster sessions might be conducted (cf. Berli et al., 2016; Knäuper et al., 2018) following the first intervention to integrate initial plan attainment experiences into plan adjustments (Scholz, Ochsner, & Luszczynska, 2013).

To conclude, the dyadic planning intervention yielded no overall improvements for target persons' long-term MVPA and physical fitness. Improvements regarding physical fitness were found for dyadic planning partners who provided (plan-related) support in the intervention sessions. Beneficial effects of support provision and its implications for dyadic planning interventions should be followed up in future research.

CRediT authorship contribution statement

Jan Keller: Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization. **Diana Hilda Hohl:** Methodology, Investigation, Writing - review & editing. **Georg Hosoya:** Software, Formal analysis, Writing - review & editing. **Silke Heuse:** Conceptualization, Methodology, Software, Writing - review & editing, Funding acquisition. **Urte Scholz:** Writing - review & editing. **Aleksandra Luszczynska:** Writing - review & editing. **Nina Knoll:** Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

None of the authors have any financial interest or benefit arising from the direct applications of their research.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2020.101710.

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